Report on Visit to Queen's University Belfast by International Training Program

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I have studied the interaction of atmospheric pressure plasma jet with a liquid at Queen's University Belfast. I stayed at Prof. Graham's laboratory. The duration of visit was two months (January 9 to March 8). The summary of the visit is reported below.

Introduction of Belfast and Queen's University Belfast

Belfast is the capital of North Ireland. The city has a population of about 270,000. The main industries in the city are linen, rope and shipbuilding. Titanic was built by Harland and Wolff shipyard in Belfast. There are Titanic Dock and Pump House and Harland & Wolff's gantry cranes (Fig. 1) which are located in the northeast of city center.

Queen's University Belfast was founded by Queen Victoria in 1845 and has a record of academic achievement which stretches back more than 150 years. The main campus is located in south of Belfast. The university is a member of the Russell Group of the UK's top 20 research-intensive universities and provides a high degree of education based on world-class research.

Life in Belfast

I home-stayed with Mr and Mrs. Gould who were introduced by Queen's University, because student residence was full. The house of Gould is conveniently placed, because it is a five minute walk from the University and there are many restaurants and supermarkets. They allowed me to use home electronics and kitchen freely. In addition they sometimes invited me to dinner on weekend. They were very hospitable.

In the laboratory everyone does a research at their

Fig. 1 Harland & Wolff's gantry cranes

Fig. 2 Queen's University Belfast

Fig. 3 City Hall Belfast

own pace and discusses at a meeting on Tuesday. One or two students give a presentation about the progress of their research using slides and discuss. Students other than speaker briefly report their situation. If we want to discuss other dates than Tuesday, Prof. Graham kindly agrees to discuss.

On weekend I went to sightseeing. There are City Hall, Grand Opera House in city center, Dock and Pump House in port, Pease walls in west side. I learned history and culture of Belfast by seeing them.

Research activity

I studied the interaction of atmospheric pressure plasma jet with a liquid.

Non-thermal atmospheric pressure plasma has attracted much attention for biomedical application and liquid processing which can not be treated at high temperature and under vacuum. However, the interaction of plasma with liquid has not been well understood. In order to develop the application of atmospheric pressure plasma, it is necessary to clarify the interaction. In this study, diagnostic of atmospheric pressure plasma with exposing to liquid was carried out to clarify the interaction.

The experimental setup is shown in Fig.4. He gas was introduced in to a glass tube with two electrodes. The upper electrode was grounded and bipolar impulse high voltage was applied to lower electrode to generate a plasma jet. The voltage was 6 kV and pulse frequency was 20 kHz. The plasma jet was exposed to

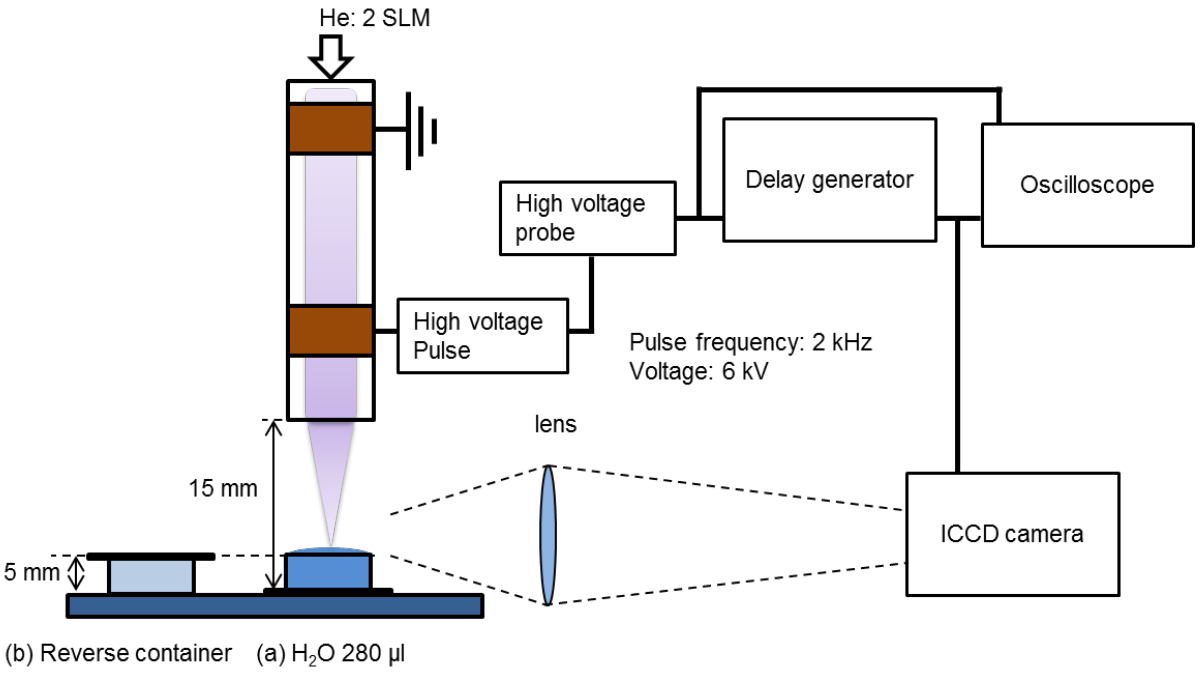

Fig. 4 Experimental setup

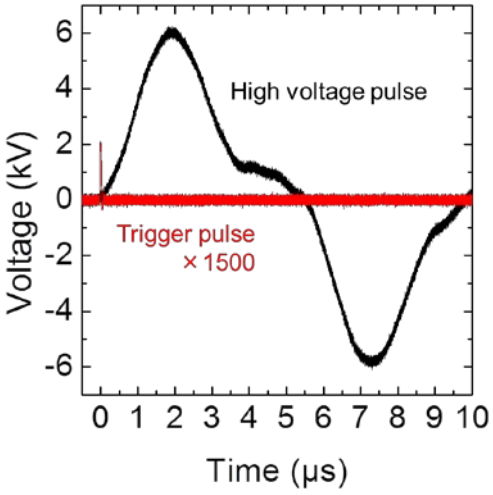

Fig. 5 Pulse voltage and triggering pulse generated by DDG.

distilled water of 280 μl. The distance of glass tube and bottom of the container was 15 mm. In order to observe the difference of liquid and solid, the empty container was reversed and put on the stage to adjust the distance of glass tube and reverse surface of container to be same with the surface of distilled water.

In order to observe the plasma jet when it is exposed to liquid sample, optical emission of plasma was measured with an intensified charge-coupled device (ICCD) camera. A digital delay generator (DDG) was connected to the pulse power supply through a high voltage probe and generated a pulse signal to trigger the ICCD camera. The waveform of pulse high voltage and triggering pulse generated by DDG are shown in Fig. 5.

Figure 6 shows pictures of optical emission of plasma when the gate width of ICCD camera is 5 μs which corresponds to positive peak of pulse high voltage. In the pictures horizontal broken line shows a position 10 mm apart from glass tube. The graph lying to the left of pictures shows optical emission intensity at the position of vertical dashed line. In both cases of (a) distilled water and (b) reverse container strongest optical emission was observed around surface.

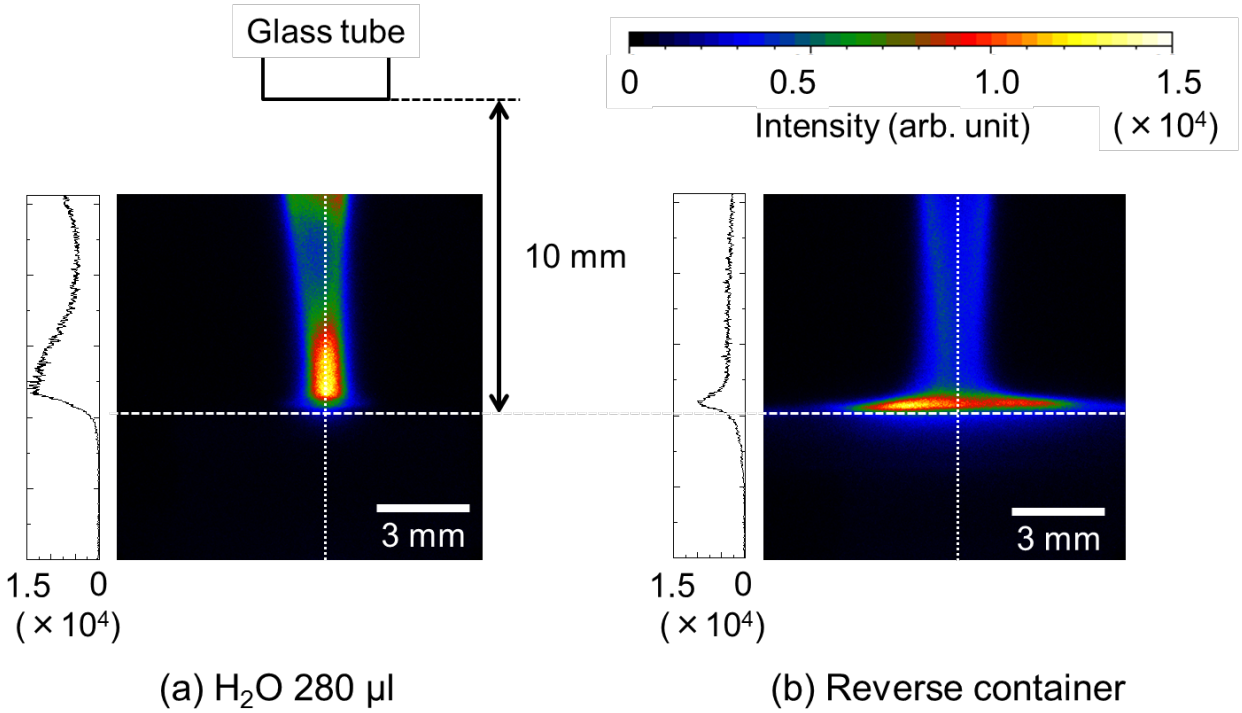

Fig. 6 Pictures of atmospheric pressure plasma exposed to (a) distilled water and (b) reverse container.

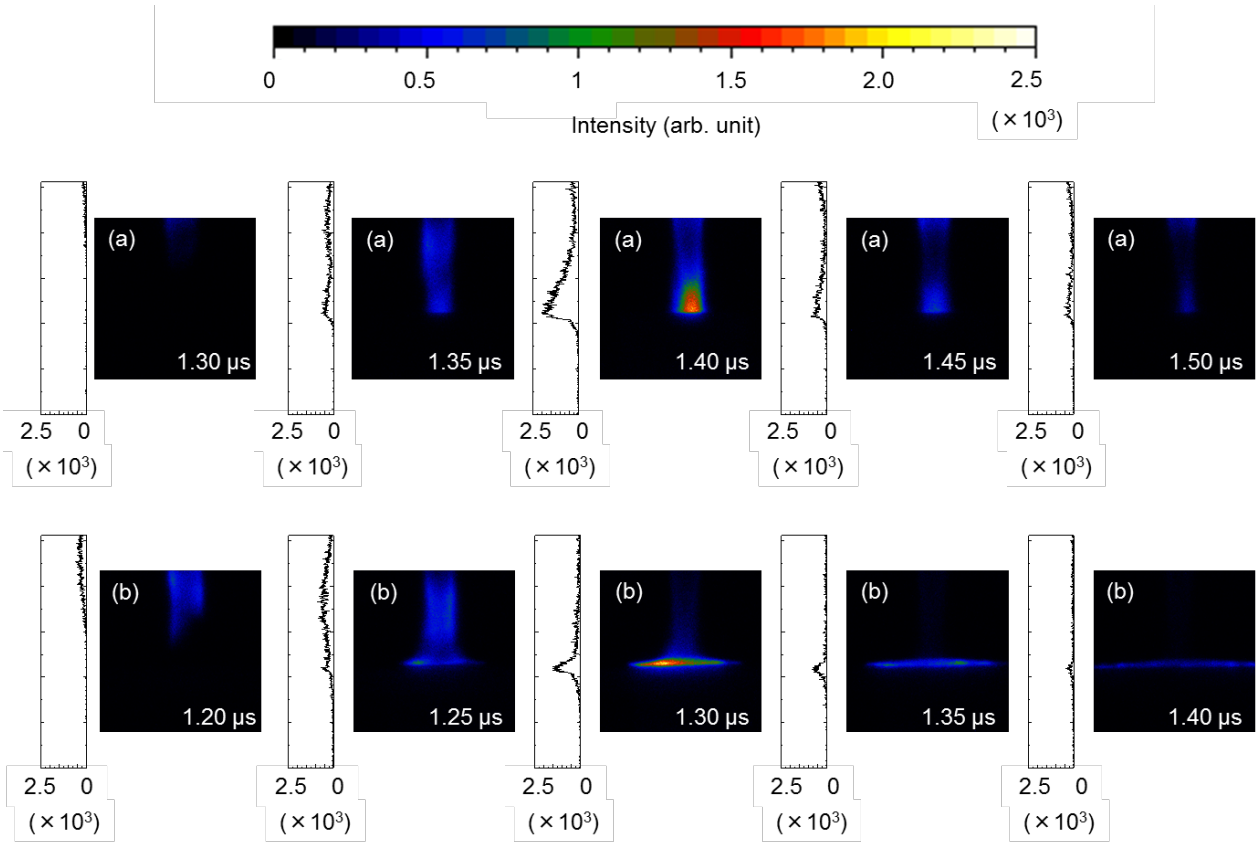

Fig. 7 Pictures of time-resolved measurement of atmospheric pressure plasma with (a) distilled water and (b) reverse container.

However, only in the case of (a), relatively strong emission was observed in the upper region.

In order to evaluate propagating of plasma, time-resolved measurement was carried out. Figure 7 shows optical emission plasma taken every 50 ns by ICCD camera with the gate width of 20 ns. The graph lying to the left of pictures shows optical emission intensity at the same position with Fig. 6. A delay time from triggering pulse is shown at the bottom right of pictures. In the case of (a), plasma propagated from glass tube and hit the surface of distilled water (1.40 μs) followed by optical emission around upper region (1.45 μs, 1.50 μs). On the other hand, no optical emission was observed around upper region (1.35 μs、1.40 μs) after plasma hitting the surface of container (1.30 μs) in (b). It is probably due to that secondary electron and exited species were generated by plasma hitting the surface of liquid. In this study, further measurement and analysis will be carried out to clarify the mechanism.

In this visiting I have constructed measurement system of the atmospheric pressure plasma jet with ICCD camera and succeeded in observing the plasma jet with liquid sample. The experiences aboard such as experiments, meetings and discussion are benefit for promoting my study in Japan.

Finally, I would like to appropriate Prof. Graham give me a chance to visit Queen's University and study there, all staff and students they help me so much. I also appreciate Prof. Hori, Prof. Toyoda, secretary of ITP office support my visiting.